I have made no mention of the changes which occur in the urine as the result of disease, for the reason that I purpose devoting a special article to this subject, which is at present under investigation, though necessarily slow in progress, and far from being completed.

It is singular to observe that any important derangement of the horse's health is associated with an acid urine, the presence of uric acid and large phosphates, and the production of a clear human-like urine in appearance; this change is produced as soon as the animal refuses food and commences to live on its own tissues.

IX. "A Chemical Inquiry into the Phenomena of Human Respiration." By William Marcet, M.D., F.R.S. Received June 3, 1889.

(Abstract.)

Before entering upon this communication, I must beg to acknowledge the valuable aid of my assistant, Mr. C. F. Townsend, F.C.S., to whose diligent, methodical, and careful work I am greatly indebted for the results obtained in the present research. The numerous calculations have all been made by both of us together, and the results checked in every possible way to insure accuracy.

My attention was first turned to the chemical phenomena of respiration in 1875, and since then I have had the honour of communicating to the Royal Society a succession of papers on the "Influence of Altitude on Respiration," which have appeared in vols. 27, 28, 29, and 31 of the 'Proceedings.'

These inquiries show in a most conclusive manner that altitude exerts an action on respiration depending entirely on the fall of atmospheric pressure. The law can be expressed as follows:—The volumes of air breathed, reduced to 0° C. and 760 mm., in order to yield the oxygen necessary for the production of a given weight (say, 1 gram) of carbonic acid, are smaller on mountains under diminished pressures than in the plains under higher pressures.

My earliest experiments on the Breithorn, 4171 metres (13,685 feet); the Col St. Théodule, 3322 metres (10,899 feet); the Riffel, 2368 metres (8428 feet); St. Bernard, 2473 metres (8115 feet); and the Col du Géant, 3362 metres (11,030 feet), were all attended with a fall of temperature on reaching into higher altitudes. This circumstance necessarily produced an increased combustion in the body, to overcome the action of the cold, and introduced an element in the inquiry not unlikely to interfere with the exclusive influence altitude might exert on the chemical phenomena of respiration. In order to overcome the present difficulty I spent three weeks on the Peak of Teneriffe in the summer of 1878, where the

experiments were repeated. The temperature, though varying to a slight extent at different altitudes on the Peak, was always high in the daytime; hence there was no cause for any increased formation of carbonic acid in the body towards the resistance of cold. The result was most striking. While in the cold Swiss Alps I had observed an increased expiration of carbonic acid in ascending, on the Peak of Teneriffe there was no such effect produced. The mean weight of carbonic acid expired at the three stations, by two persons, was, with one exception only, applying to a Chamonix guide, the same for each of them respectively. But the volumes of air breathed at increasing altitudes were lessened,* so that the law remained unchanged—that at increasing altitudes, less air, reduced to 0° C. and 760 mm., is required to produce 1 gram of carbonic acid in the body. The experiments on the Peak of Teneriffe, by doing away entirely with the influence of cold, place the fact beyond doubt.

As it is important towards a clear understanding of the results contained in this paper that those obtained formerly should be present to the reader, I beg to subjoin them in a tabular form.

Experiments on the Alps.

(On myself.)

Station.	Altitude.	Litres of air expired for 1 gram CO_2, reduced to 0° and 760 mm.
Near Geneva	375 m. (1,230 ft.)	13·6
St. Bernard	2473 „ (8,115 „)	Mean at and above 8,115 ft. up to 13,685 ft. 11·05
Riffel	2568 „ (8,428 „)	
St. Théodule	3322 „ (10,899 „)	
Summit of Breithorn	4171 „ (13,685 „)	

On the Peak of Teneriffe.

(On myself.)

Seaside		12·4
Guajara	2161 m. (7,090 ft.)	11·9
Alta Vista	3261 „ (10,700 „)	10·7
Foot of terminal cone	3578 „ (11,740 „)	10·6

On the Col du Géant.

(On myself.)

Near Geneva	375 m. (1,230 ft.)	15·5

* An exception again for the Chamonix guide at his highest station, although the *mean* reduced volume of air he expired at the two high stations on the Peak is lower than that he expired at the seaside by 18 per cent.

			Litres of air expired for 1 gram CO_2, reduced to 0° and 760 mm. Mean before and after ascent.
Courmayeur	1202 m.	(3,945 ft.)	14·35
Summit Col du Géant ...	3362 „	(11,030 „)	13·5

On M. David, aged 25.

Near Geneva	375 m.	(1,230 ft.)	13·7
			Mean before and after ascent.
Courmayeur	1202 „	(3,945 „)	14·8*
Summit Col du Géant ..	3362 „	(11,030 „)	12·6

The experiments were made by determining as carefully as possible the volume of air expired within a given time, and then estimating the amount of carbonic acid it contained by means of Pettenkofer's method. The volume of air, reduced to 0° C. and 760 mm. pressure, holding 1 gram of carbonic acid, was then easily calculated.

These experiments were subsequently repeated in 1882 on the Rigi Mountain in Switzerland, altitude 1594 metres (5230 feet), and as the results obtained have never been published, beyond a short reference to them in a communication to the Alpine Club, they are included in the present paper. My companion, Mr. Thury, a young engineer, aged twenty-five, submitted to the inquiry. Fifteen experiments were made near Geneva at a mean barometer pressure of 728 mm., and a mean temperature of 15·9° C., and eighteen as soon afterwards as possible on the Rigi Staffel, at a mean pressure of 639 mm., and a mean temperature of 7·6° C. As might have been expected, more CO_2 was exhaled in a given time on the cold mountain station than in the Valley of Geneva, a mean of 0·350 gram being expired near Geneva and 0·445 gram at the higher station, giving an excess of no less than 21 per cent. of carbonic acid for the Rigi. The amount of air expired—say breathed—for the expiration of 1 gram CO_2, reduced to 0° and 760 mm., was 10·78 litres in the Valley and only 9·45 on the Rigi. Therefore, for a mean difference of 89 mm. of atmospheric pressure, and with a marked fall of temperature, less air by 12 per cent. was breathed on the mountain to supply the oxygen required by the body to burn the same amount of carbon as in the valley.

The present investigation has been carried out in a laboratory of the Physiological Department at University College, which Professor Schäfer has kindly placed at my disposal. Its object was to ascertain

* This is an exceptional case, owing clearly to the small increase of altitude between Geneva and Courmayeur, which only amounts to 827 metres.

the influence of food and changes of atmospheric pressure on the volume of air breathed and weight of CO_2 expired. Two persons, my assistant, Mr. C. F. Townsend, and my laboratory attendant, William Alderwood, kindly submitted to experiment.

The person under experiment sat in a semi-recumbent posture in a deck-chair, with his feet resting on a stool, so as to do away with all muscular effort. He inspired by the nose only, and expired through the mouth into a wide india-rubber tube, connected with a bell-jar, of a capacity of over 40 litres, and suspended over salt water. The bell-jar was accurately counterpoised over a pulley fixed to a cycloid, whose leverage power, increasing as the bell-jar rose, kept the latter perfectly balanced, and therefore the air it contained was under atmospheric pressure in every position. The time for collecting the air expired was measured with a stop watch. In order to make sure of no air being expired accidentally through the nose, at the end of each inspiration the nose was closed with the index-fingers, and thus held during the expiration.

In order to obviate the objection that the attention given to the experiment might interfere with natural breathing, the air was expired into the bell-jar through a double-way cock, disposed in such a manner that the person under experiment might, unknown to him, either expire into the external air or into the bell-jar. At the commencement of the experiment he was made to expire into the open air, and when, after ten minutes or a quarter of an hour, his respiration had become perfectly regular, the stopcock was turned and the air admitted into the bell-jar. The latter was so well suspended that it rose without the least effort; thus, the person experimented upon, unless looking at the bell-jar, could not tell whether he was breathing into it or into the external air.

The carbonic acid was determined by aspiring with a pump the air from the bell-jar into a glass cylinder of a capacity of 1000 c.c., to which was subsequently screwed, air-tight, a bottle holding 100 c.c. of a normal solution of barium hydrate. After agitating the air with the akaline solution for a minute or two, about 100 c.c. of common air free from CO_2, and contained in a pear-shaped india-rubber bag, was forced into the cylinder by pressure with the hand, and then the shaking resumed for a quarter of an hour. The addition of the air caused a pressure inside the cylinder which was found to accelerate greatly the combination of the CO_2. Finally, the alkaline solution was decanted into a glass-stoppered bottle of a capacity of about 100 c.c., and the stopper secured with paraffin. The morning of the next day, when the precipitate had entirely subsided, the clear fluid was titrated with a standard solution of oxalic acid in the usual way.

A number of precautions were taken to insure the accuracy of the method; perhaps the most important was blowing, with a bellows, a

current of air over pumice-stone moistened with a solution of potassium hydrate, through the wide mouth bottle in which the titration was being made; by this means no atmospheric carbonic acid could interfere with the correctness of the result. Fourteen pairs of analyses, made to test the method, gave a mean difference of only 0·31 per cent.

Two comparative experiments were carried out in a large air-tight chamber in which a person lying in a deck-chair breathed first into an india-rubber bag, representing the bell-jar, and next into the air of the chamber. The air in the bag and in the chamber being subsequently analysed yielded practically the same weight of carbonic acid expired within the same time.*

The results obtained from the present inquiry are as follows:—

1. The law of nature is further demonstrated that less air, reduced to 0° C. and 760 mm. pressure, is breathed at high than at low altitudes for the formation in the body of a given weight of carbonic acid.

2. The known usual influence of food on the formation of carbonic acid in the body is confirmed—the maximum amount expired occurring between two and three hours after a meal, while the minimum is before breakfast.

3. The influence of food on the relation between the volumes of air breathed (reduced) and the corresponding weights of carbonic acid expired is clearly shown; the volumes following, as a rule, the fluctuations of the carbonic acid, but there is apparently a sudden change in this relation at a period of between four and five hours after a meal, when the carbonic acid expired falls proportionally faster than the volumes of air breathed. The harmony of the tracings in one of the charts accompanying my paper has recovered itself, however, overnight, and the lines are again nearly parallel before the first morning meal. In the other chart there are no experiments recorded made before breakfast.

4. The local state of the atmospheric pressure, as shown by the barometer, has a marked influence on respiration, less air, reduced to 0° C. and 760 mm. pressure, being taken into the lungs for the formation and emission of a given weight of carbonic acid under *lower* atmospheric pressures than under *higher* pressures; but this influence varies in degree according to different persons. In the present inquiry when two young men were experimented upon—in one case, for a fall of pressure of 10 mm. (0·395 inch), there was a mean reduction of 1·076 per cent. of the volume of air breathed for 1 gram CO_2 expired; in the other case, the mean reduction was greater, and amounted to 1·745 per cent.

5. The above influence of local atmospheric pressures on the volume of air breathed is not the same throughout the whole day, being much less marked from two to four hours after a meal when the action of

* In one experiment the difference amounted to 2·97 per cent.; in the other to 0·6 per cent. only.

food is at its maximum. Thus digestion neutralises in a great measure the effects on respiration of any local change of pressure.

Two persons, both aged twenty-three, were found in the experiments related in this paper to require respectively a mean of 9·29 and 10·51 litres of air, reduced, to expire 1 gram carbonic acid. Experiments on another person, aged sixty, gave a mean of 11·30 litres of air; and with a number of others the proportion of air breathed for a given weight of carbonic acid expired also varied, showing that different individuals breathe different volumes of air to supply their body with the necessary amount of oxygen to make and expire a given weight of carbonic acid. It cannot be doubted that the less the volume of air inspired to burn a certain weight of carbon, the more readily the oxygen taken into the lungs finds its way into the blood, and, therefore, the more perfect the respiratory function. This may have important bearings in medical respects. The age of sixty years apparently necessitated breathing a comparatively large proportion of air (11·30 litres) to supply the blood with the oxygen it required. One of the two young men was physically stronger and possessed of a greater muscular development than the other, he breathed 9·29 litres against 10·51 for the other, or took 11·6 per cent. less air into his lungs to yield the necessary oxygen to burn the same weight of carbon within a given time. The corresponding difference between the person aged sixty, and the strongest of the two young men amounted to no less than 17·8 per cent.

X. "On a Pure Fermentation of Mannite and Glycerin." By PERCY F. FRANKLAND, Ph.D., B.Sc. (Lond.), Assoc. Roy. Sch. of Mines, Professor of Chemistry in University College, Dundee, and JOSEPH J. FOX. Communicated by Professor T. E. THORPE, F.R.S. Received June 17, 1889.

Although the fermentative action of micro-organisms has from time to time attracted the attention of numerous investigators, both chemical and biological, still in by far the majority of cases there has been absolutely no guarantee that the chemical changes observed were the result of the activity of a pure growth of one organism and not of a more or less complex mixture of organisms. Indeed, it is only within recent years that the most familiar of all fermentations—the alcoholic—has been induced with growths of yeast definitely ascertained to be of absolute purity.

Thus whilst Pasteur and others had many years previously studied the fermentation of sugar induced by yeast, free from bacteria and other micro-organisms, it is to Hansen that we owe the systematic investigation of the fermentations caused by distinct kinds of yeast in a state of unquestionable purity.